## 4.4 Geological Resources

This section addresses and outlines the geologic setting and geologic impacts relevant to the Project Area and the proposed Project. These impacts involve the geologic structure, geomorphology, tectonic setting, and physical geologic properties of the Project Area. Utilizing thresholds of significance, this section assesses geologic hazards and provides mitigation measures to remediate any significant geological hazards associated with the Project.

### 4.4.1 Environmental Setting

#### 4.4.1.1 Physiography

The Whittier Main Oil Field is located in the Puente Hills, a northwest-southeast-trending series of hills along the northeast perimeter of the Los Angeles Coastal Plain (Figure 4.4-1). These hills, which reach a maximum height of 1,800 feet above mean sea level, consist of moderate to steep canyons and gullies with intervening ridges. The topography of the Puente Hills, within the Whittier Main Oil Field, has been locally modified by creation of numerous oil field service roads and relatively flat well-drilling pads. Steep cut slopes, with gradients up to approximately ¾:1 (horizontal to vertical) to near-vertical, are present along many of the roads and on the perimeter of apparently old well pads. Natural slopes are locally eroded with steep-sided gullies.

The Project Site, comprised of the proposed consolidated drilling site, is located along the canyon floor of La Canada Verde, at the base of a moderate- to steeply-sloping, southwest facing hillside. The canyon floor is relatively broad, partially due to fill overlying a portion of (culverted) La Canada Verde Creek, and bordered on each side by slopes having gradients estimated at two horizontal to one vertical (2:1) or steeper. The proposed drilling pad is irregular in shape, running parallel to the canyon floor. Much of the Project Area topography has been altered extensively by past grading. Roadways, both paved and unpaved, traverse most of the area, including those cut into hillsides and traversing canyons. Level building pads have been excavated into the hillsides and occupy much of the flat-lying alluvial canyon bottom areas. Portions of the slopes, such as along the creek banks of La Canada Verde creek, have been over-steepened as a result of prior grading operations. Cut slopes are abundant and exposed along the roadways throughout the Project Area. Fill areas are also present (Heathcote Geotechnical 2011).

From the Preserve boundary to the proposed oil and gas pipeline tie-ins, the pipeline route follows an existing paved roadway, along which the topography is initially gently to moderately sloping, becoming relatively flat in the southern portions of the alignment (Figure 4.4-1). The upper, northern portion of the pipeline traverses slopes on both sides of Arroyo Pescadero.

#### 4.4.1.2 Regional Geologic Setting

The Project Area is located within the Los Angeles Basin, which encompasses two major active fault systems, including the northwest trending, strike-slip, San Andreas-type faults of the

Peninsular Geomorphic Province and the east-west trending, mostly left-lateral and compressional reverse faults of the Transverse Ranges Geomorphic Province.

The Puente Hills are bound by the San Gabriel Valley on the northwest, the San Bernardino Valley on the northeast, and the Los Angeles Basin to the south. The Puente Hills expose a Miocene marine sedimentary sequence, composed of the Monterey (Puente) Formation, of late Miocene age (Figure 4.4-2). The Monterey Formation is divided roughly into two siliceous shale members, separated by a sandstone member. These units are then in turn overlain by the Sycamore Canyon Formation, late Miocene age, which is composed of predominately clastic sediments. Along the northwest margin of these hills and south-southwest of the Whittier Fault, this formation is overlain by the mostly marine, clastic, Pliocene Fernando Formation, which in turn is unconformably overlain by the San Pedro shallow-marine sand and La Habra older alluvial sediments, both Pleistocene in age.

Structurally, the Puente Hills are the surface expression of the south vergent, Puente Hills thrust fault. Cutting through the foothills of the Puente Hills is the Whittier Fault, which is classified as an active fault by the California Geological Survey (CGS) (see Figures 4.4-2 and 4.4-3) (Grant and Gath 2007). The northeast side of the Puente Hills is partly bound by the Chino Fault, which is a splay of the Whittier fault. Section 4.4.1.4, Faulting and Seismicity, contains additional information regarding faulting in the vicinity of the Project Site.

### 4.4.1.3 Local Geologic Setting

The Project Site is underlain at the surface by artificial fill, up to 10 feet thick, Pleistocene older alluvium, up to 25 feet thick, and the Pliocene Fernando Formation. The following summary of on-site geologic materials is based on a geotechnical investigation of the Project Site (Heathcote Geotechnical, Inc. 2011).

#### Artificial Fill

Artificial fill consists of sandy clay to sandy silt. The fill material contains concrete and asphalt in a loose, uncompacted manner. Fill depths are up to 10 feet deep in the areas sampled. Heathcote Geotechnical lab testing found very low to medium expansion potential in the fill.

#### Landslide Deposits

Previous exploratory mapping suggested a landslide on the northern portion of the Project Site. Further studies indicated no existing landslide in this area.

#### Older Alluvium

Older alluvium deposits consist of tan to light brown or light reddish brown, silty sand with small sub-rounded gravel. The deposits are generally dense. Lab testing performed by Heathcote found the soils to have very low to medium expansion potential.

**Figure 4.4-1 Topography of the Whittier Main Oil Field Development Project**

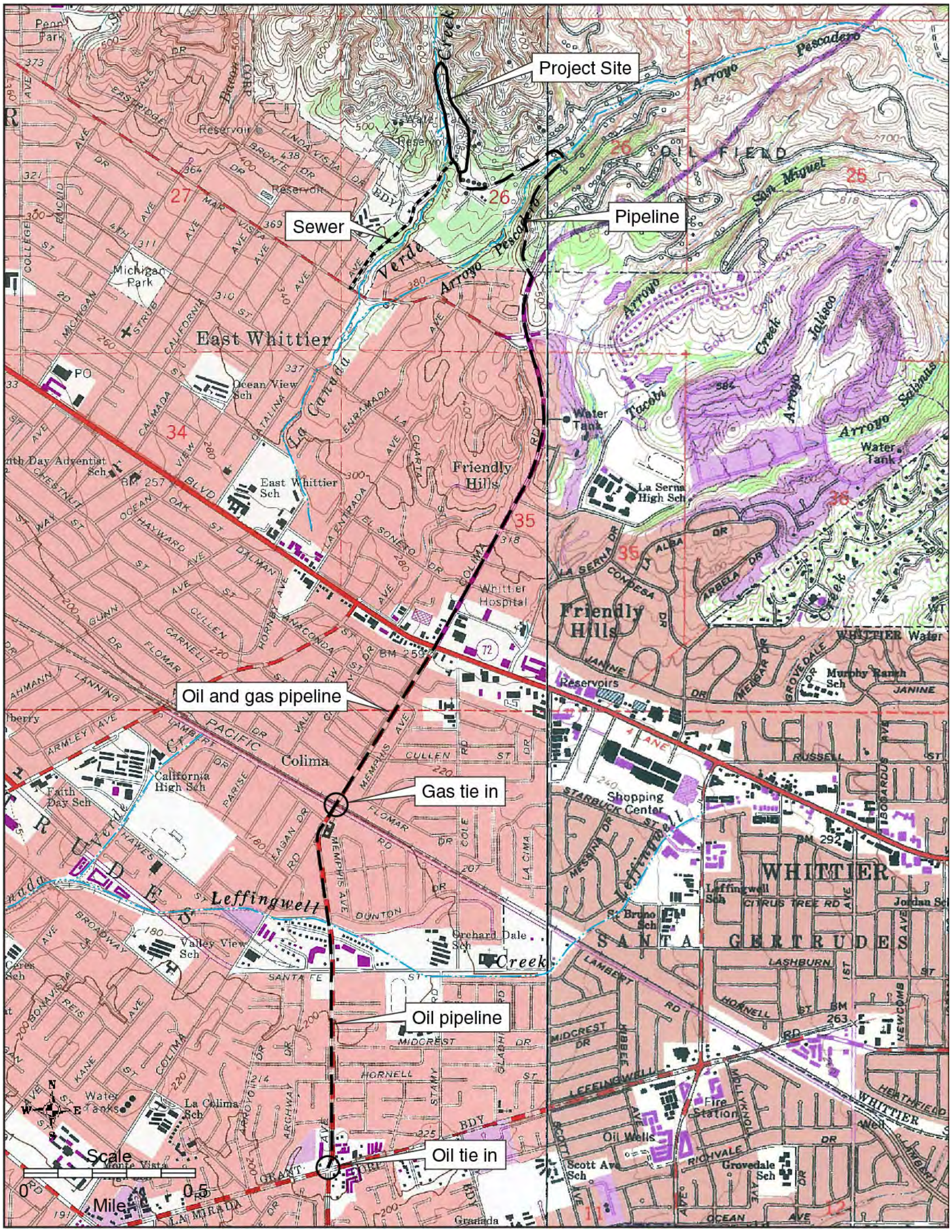
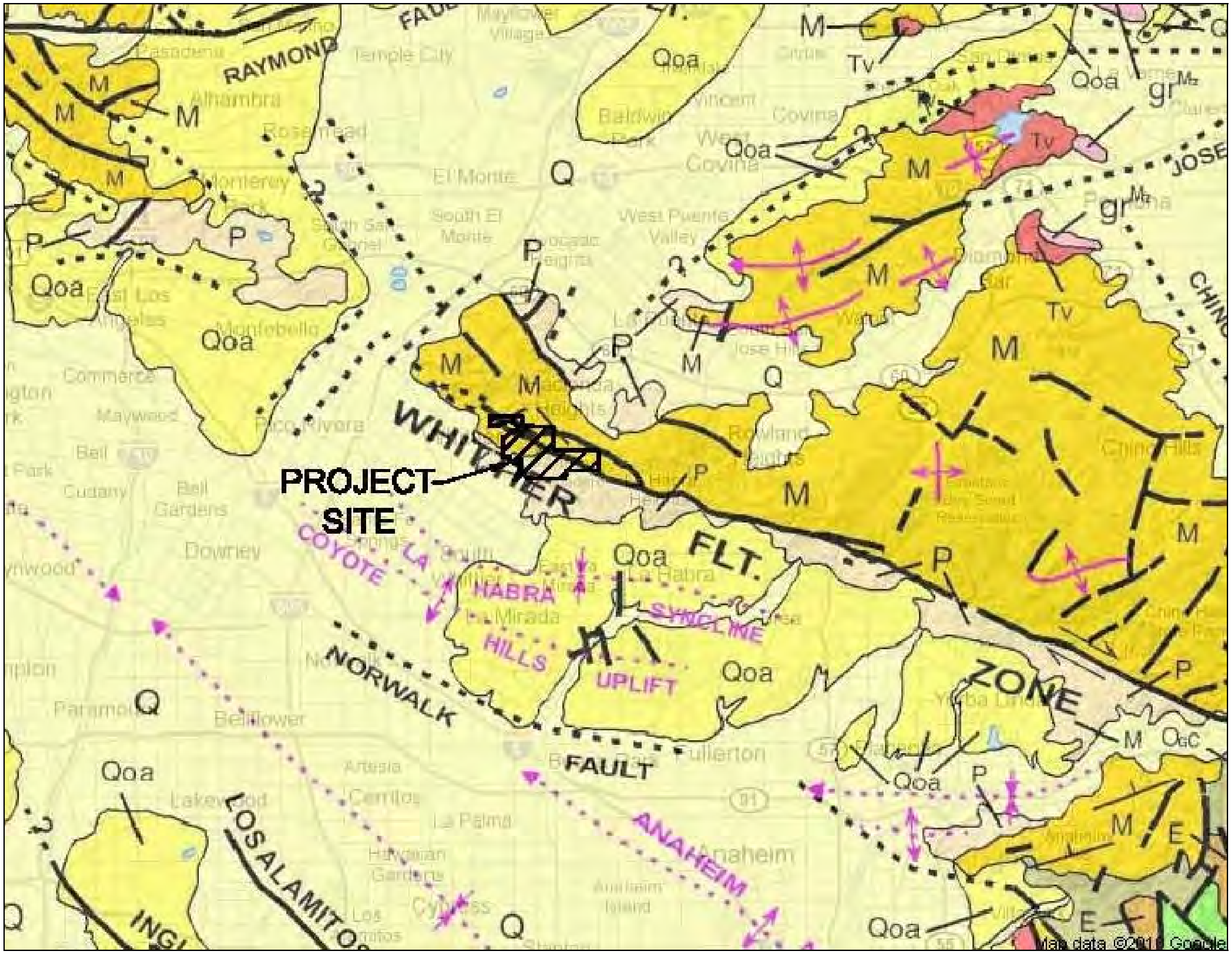
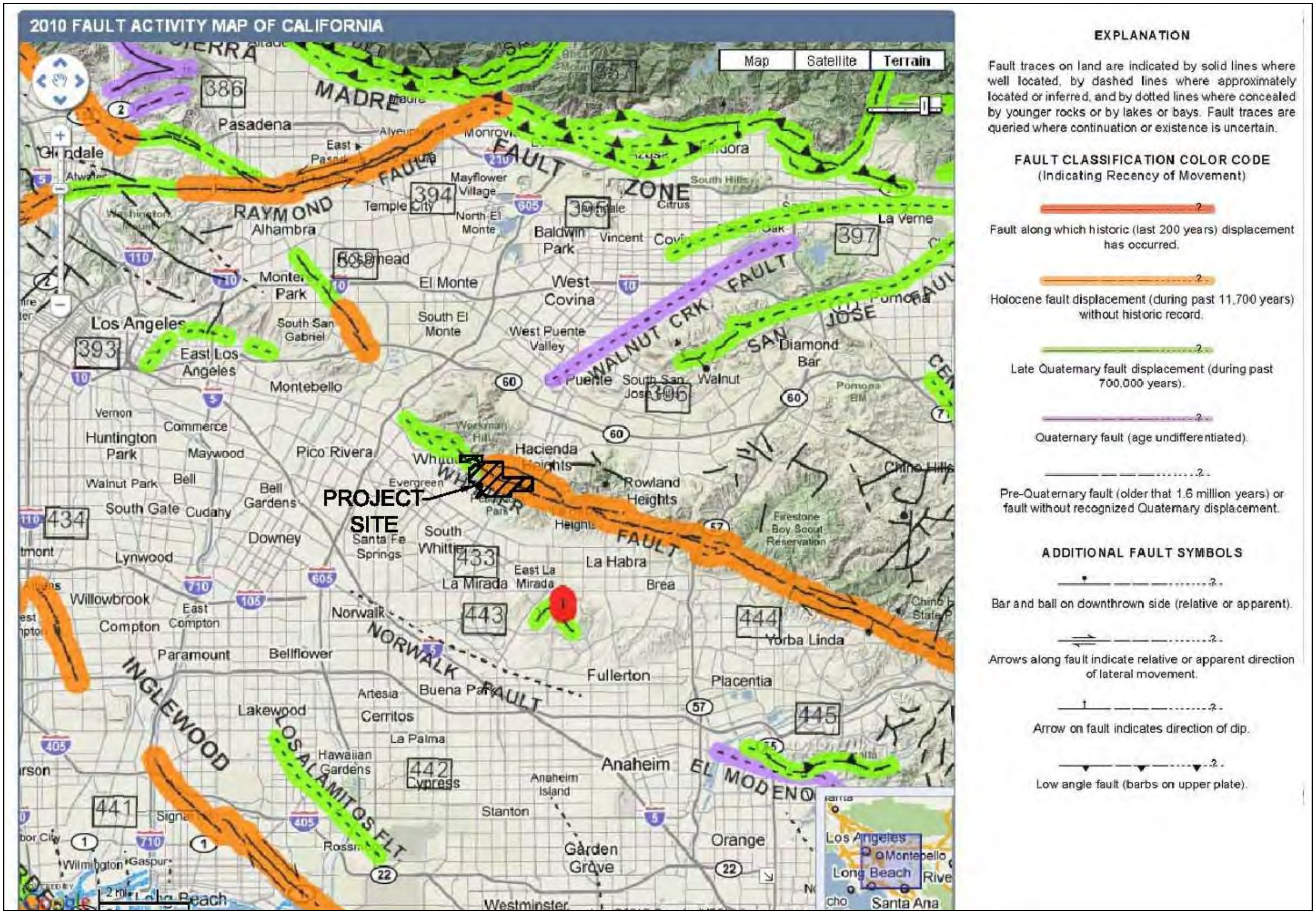


**Figure 4.4-2 Regional Geologic Map**




Source: California Geological Survey 2010a

**Figure 4.4-3 Regional Faults and Fault Activity**




Source: California Geological Survey 2010b

### Younger Alluvium

Younger alluvium deposits consist of loose sand and/or gravels associated with the active area of the streambeds. The younger alluvial soils may be prone to hydroconsolidation.

### Bedrock

The bedrock across the site consists of Fernando Formation, which is comprised of yellow brown siltstone and silty fine-grained sandstone, vaguely interbedded with gray claystone, or buff fine to medium grained sandstone. The sandstone facies consist of light gray to rust brown, fine- to coarse-grained, thickly bedded sandstone and pebble conglomerate, with local fossil deposits. The sequence is moderately well cemented but friable on weathered surfaces. The bedrock materials are fairly dense and firm. These soils are not susceptible to hydroconsolidation, but have a mild consolidation potential.

## 4.4.1.4 Geologic Hazards

### Faulting and Seismicity

*Regional Seismicity*

The seismicity of southern California is dominated by the intersection of the northwest-trending San Andreas Fault System and the east-west trending Transverse Ranges Fault System. The Los Angeles Basin is located at the intersection of these two systems. Both systems are responding to strain produced by the relative motions of the Pacific and North American tectonic plates. The strain is relieved by right lateral strike slip faulting on the San Andreas and related faults and by vertical, reverse slip, or left lateral, strike slip displacement on faults in the Transverse Ranges. The effects of this deformation include mountain building, basin development, deformation of Quaternary marine terraces, widespread regional uplift, and generation of earthquakes.

The Project Area is subject to strong seismically induced ground shaking, as several active and potentially active faults are located in the region. Table 4.4-1 lists the ten closest faults and distance in miles from the Project Area, the maximum magnitude, estimated peak ground acceleration, and the slip rate. In addition to the faults listed in Table 4.4-1, blind thrust faults (as described below) and other large faults in the southern California area could impact the site, including the San Andreas Fault (33 miles east) and the San Jacinto Fault (34 miles southeast).

Most recently, the Los Angeles Basin was subject to earthquakes generated by movement on thrust faults associated with the Transverse Ranges Fault System. Active reverse or thrust faults include the blind thrust faults (i.e., reverse faults that have no surface exposure) responsible for the 1987 Whittier Narrows magnitude 5.9 earthquake and the 1994 Northridge magnitude 6.7 earthquake (Shaw and Shearer 1999; Southern California Earthquake Data Center 2007). The Project Area overlies the Puente Hills blind thrust system, an active blind thrust fault system, which extends for more than 24 miles in the northern Los Angeles Basin, from downtown Los Angeles east to Brea, in northern Orange County. Potential earthquakes on the Puente Hills blind thrust fault beneath the Los Angeles area could result in 3,000 to 18,000 fatalities, 142,000 to 735,000 displaced households, and more than 250 billion dollars in total damages (Southern California Earthquake Center 2005).

Puente Hills thrust fault system includes at least three distinct segments, which from west to east include the Los Angeles, Santa Fe Springs, and Coyote Hills segments. The Project Area appears to overlie the Coyote Hills segment of the thrust fault. This fault appears to have generated the 1987 Whittier Narrows earthquake. If these segments rupture independently, magnitude 6.5 to 6.6 earthquakes are likely; however, if multi-segments rupture, earthquakes up to magnitude 7.5 could occur (Southern California Earthquake Center 2003). Slip rates suggest that earthquakes would occur every 400 to 1,320 years on individual segments and 780 to 2,600 years on multi-segments. Surface rupture attributable to these deep seated, blind-thrust seismic sources does not appear to be likely within the Project Area, but the presence of these blind thrust faults will potentially contribute to strong seismically induced ground shaking (Heathcote Geotechnical 2011; Shaw 2002).

However, surface fault rupture is possible along the active Whittier Fault, located approximately 1,500 feet north of the Project Site and 1,500 feet northeast of the proposed pipeline alignment, at the closest point (California Geological Survey 2010). The California Geological Survey (formerly the California Division of Mines and Geology) defines active faults as those along which movement has occurred within Holocene time (approximately the last 11,000 years) (California Department of Conservation, Division of Mines and Geology 1994). The Whittier Fault comprises the northernmost segment of the larger Elsinore Fault Zone, which extends across the Santa Fe Springs and Coyote Hills segments of the Puente Hills Thrust Fault. The Whittier Fault is exposed along the southern slopes of the Puente Hills and has a length of approximately 25 miles, between the Whittier Narrows at the northwest and the Santa Ana River to the southeast (Heathcote Geotechnical 2011). Based on this fault length, the Whittier Fault is capable of generating a maximum earthquake of moment magnitude 6.0 to 7.2 (Southern California Earthquake Data Center 2011).

Some researchers postulate that, based on data from the 1987 Whittier Narrows earthquake, the Whittier Fault turns northerly west of the Puente Hills, traverses the Whittier Narrows, and connects with the Montebello Fault (e.g., Dolan et al. 2001). This increased fault length could increase the maximum anticipated earthquake, as maximum probable earthquakes of strike-slip faults are based in part on the length of the fault. However, the surface expression of the fault across the Whittier Narrows is absent; therefore, the Southern California Earthquake Data Center maintains a maximum earthquake of moment magnitude 6.0 to 7.2 (SCEDC 2011).

Portions of the active Whittier Fault, including the portion of the fault closest to the Project Area, have been included within an Alquist-Priolo Fault Zone. Construction within such a zone requires that special geologic studies be conducted to locate and assess any active fault traces in and around known active fault areas prior to development of structures for human occupancy (see Section 4.4.2, Regulatory Setting, for additional information). No Alquist-Priolo Fault Zones are present within the Project Area.

**Table 4.4-1 Partial List of Nearby Regional Surface Faults**

| Fault Name | Distance Between Site and Surface Projection of Earthquake Rupture (miles) | Estimated Maximum Earthquake (MW) | Slip Rate (mm/year) | Fault Type |
|---|---|---|---|---|
| Elsinore-Whittier | 0.5 | 7.2 | 2.50 | SS |
| San Jose | 8.8 | 6.5 | 0.50 | DS |
| Raymond | 13.1 | 6.5 | 0.50 | DS |
| Chino-Central Ave. (Elsinore) | 14.1 | 6.7 | 1.00 | DS |
| Sierra Madre (Central) | 15.0 | 7.0 | 3.00 | DS |
| Verdugo | 15.0 | 6.7 | 0.50 | DS |
| Clamshell-Sawpit | 16.0 | 6.5 | 0.50 | DS |
| Newport-Inglewood | 16.5 | 6.9 | 1.00 | SS |
| Hollywood | 17.2 | 6.5 | 1.00 | DS |
| Cucamonga | 19.50 | 7.0 | 5.00 | DS |

Notes: SS = Strike Slope Fault; DS = Dip Slip Fault
Source: EQFAULT, Southern California Earthquake Data Center, and USGS

*Ground Shaking*

The energy released during an earthquake propagates from its rupture surface as seismic waves. The resulting strong ground motion from the seismic wave propagation can cause significant damage to structures. At any location, the intensity of the ground motion is a function of the distance to the fault rupture, the local soil and bedrock conditions, and the earthquake magnitude. Intensity is usually greater in areas underlain by unconsolidated material than in areas underlain by more competent rock.

Earthquakes are characterized by a moment magnitude, which is quantitative measure of the strength of the earthquake based on strain energy released during the event. The magnitude is independent of the site, but it is dependent on several factors including the type of fault, rock type, and stored energy. Moderate to severe ground shaking would affect the Project area if a large magnitude earthquake occurred on one of the nearby principal late-Quaternary faults.

Based on the analysis, historical records indicate that the Project area has experienced shaking from a number of seismic events over the last 150 years. The seismic events that likely caused varying degrees of ground motion at the Project Site include earthquakes in 1812, 1827, 1852, 1855, 1857, 1893, 1936, 1952, 1956, 1965, 1971, 1974, 1977, 1987, 1991, and 1994. The 1812 and 1857 events are thought to have occurred along the Mojave Segment of the San Andreas Fault and caused significant damage to developed areas of southern and central California. Those earthquakes were estimated to have had moment magnitudes of approximately M7.1 and 7.8, respectively. The 1952 Tehachapi earthquake had an estimated moment magnitude of M7.7. The 1987 Whittier Narrows earthquake damaged more than 10,000 buildings in the Whittier area and destroyed 123 single-family homes. The earthquake measured 5.9 on the Richter scale and produced a peak measured acceleration of 0.63g 6 miles from the epicenter.

Ground shaking is primarily a function of the distance between an area and the seismic source, the type of materials underlying the site, and the motion of fault displacement. In addition, the 1994 Northridge earthquake showed how peculiarities in basins and other topographic effects could play significant roles in ground accelerations at particular areas. For instance, ground accelerations exceeding 1g were recorded far from the epicenter of the Northridge earthquake. It is possible that accelerations near or over the upper-bound earthquake ground motion could occur anywhere within or adjacent to the Project area.

*Probabilistic Ground Acceleration Analysis*

The California Geological Survey has prepared probabilistic seismic hazard maps, expressed in terms of the probability of exceeding a certain ground motion. For example, the 10 percent probability of exceedance in 50 years maps depict an annual probability of 1 in 475 of being exceeded each year. These maps have been prepared for use in designing buildings in high seismic areas. The maps for 10 percent probability of exceedance in 50 years show ground motions that the California Geological Survey do not believe will be exceeded in the next 50 years. In fact, there is a 90 percent chance that these ground motions would not be exceeded. This probability level allows engineers to design structures for larger ground motions than what is expected during a 50 year interval. At the Project Area, there is a 10 percent probability of exceedance of ground acceleration of 0.4 to 0.5 g (percent of gravity) (California Geological Survey 2011).

In confirmation of the maps described above, Project Site-specific acceleration values of 0.4861 g to 0.475 g were calculated. Based on these predicted ground accelerations and underlying earth material conditions, moderate to severe ground shaking due to a seismic event on a nearby fault could potentially cause damage to the proposed structures (Heathcote Geotechnical 2011).

Vertical ground accelerations have not been developed for the site. Past studies determined that at close distances and for large earthquakes, the peak vertical accelerations can be approximately 1.6 times the peak horizontal acceleration (Borzorgnia et al. 1999).

Earthquakes and Petroleum Facilities

Worldwide, earthquake performance at various types of petroleum facilities has been excellent from the standpoint of direct damage, but several significant instances of damage have occurred as a result of fire following an earthquake. In the 1952 Kern County earthquake (magnitude 7.3), the Paloma Cycling Plant survived the earthquake until two large butane spheres collapsed, releasing highly volatile material, which spread quickly and was ignited within minutes. The 1964 Niigata, Japan, earthquake (magnitude 7.5) resulted in fire at the Showa Oil Company refinery, which burned continuously for 2 weeks. In addition, fire occurred at failed storage tanks following the 1964 Alaska earthquake (magnitude 8.4). However, during the 1971 San Fernando earthquake (magnitude 6.4) in the northern Los Angeles area, damage to refineries in the vicinity of the epicenter was limited to internal piping and some storage tanks. Similarly, oil lines were not damaged during the 1979 Imperial Valley earthquake (magnitude 6.4) and pipeline damage was minimal during the 1983 Coalinga earthquake (magnitude 6.4) (California Department of Conservation, Division of Mines and Geology 1988).

The low earthen embankments used as retention dikes around oil storage tanks are subject to failure from earthquake shaking. Damage to storage tanks is commonly due to the sloshing of liquids that damages or destroys the fixed or floating tank tops. Tank piping often breaks when it does not possess sufficient flexibility. Historically, while the spillage of oil has sometimes been considerable, these spills have not been serious when contained within dikes and kept free of ignition sources (California Department of Conservation, Division of Mines and Geology 1988).

**Secondary Seismic Hazards**

Potential hazards resulting from the secondary effects of groundshaking include: liquefaction, lateral spreading, differential settlement, and landslide-induced earthquakes.

*Liquefaction*

Liquefaction is a type of ground failure that occurs as a result of loss of shear strength or shearing resistance in loose and sometimes medium dense, cohesionless soils, due to seismically induced ground shaking. Liquefaction typically occurs in sediments where static, relatively widespread groundwater is less than 50 feet (15 m) below ground surface.

Factors that affect the degree of liquefaction include:

- Magnitude and proximity of the earthquake;
- Duration of shaking;
- Soil types;
- Grain size distribution;
- Clay fraction content;
- Density;
- Angularity;
- Effective overburden;
- Cyclic loading; and
- Soil stress history.

Portions of the Project Area are located within an area of potential liquefaction, as delineated by the Department of Conservation Seismic Hazard Zones Maps (California Department of Conservation, Division of Mines and Geology 1999). The Recent alluvial sediments within La Canada Verde, located immediately adjacent to the Project Site, and Arroyo Pescadero, which is traversed by the proposed pipeline alignment (Figure 4.4-1), are prone to liquefaction. Although the pipeline route would locally be susceptible to liquefaction where it traverses Arroyo Pescadero, the Project Site would not be, as it is topographically higher than the alluvial sediments prone to liquefaction. Geotechnical borings drilled at the Project Site, to a depth of 60 feet in 2009 and 2010, did not encounter groundwater (Heathcote Geotechnical 2011). Other than creek areas, where localized perched groundwater may be present, historical groundwater is deeper than 100 feet beneath the Project Site (California Department of Conservation, Division of Mines and Geology 1998). A liquefaction analysis completed in conjunction with these geotechnical borings indicated that the soil profile will most likely not experience liquefaction at the Project Site and liquefaction induced settlement is expected to be 0 inches (Heathcote Geotechnical 2011).

*Lateral Spreading*

Lateral spreading occurs as a result of liquefaction in which a subsurface layer becomes a liquefied mass, and gravitational and inertial forces cause the mass to move downslope. This type of failure is common in oversteepened slopes comprised of unconsolidated silts and sands. The magnitude of lateral spreading movements depends on earthquake magnitude, distance between the site and the seismic event, thickness of the liquefied layer, ground slope or ratio of free-face height to distance between the free face and structure, fines content, average particle size of the materials comprising the liquefied layer, and the standard penetration rates of the materials. Based on the soil and rock materials present within geotechnical borings drilled at the site, the potential for lateral spreading during a strong seismic event is not anticipated to occur due to the lack of liquefaction (Heathcote Geotechnical 2011).

*Differential Settlement*

Differential settlement is a process whereby soils settle non-uniformly, potentially resulting in stress and damage to pipelines or other overlying structures. Such movement can occur in the absence of seismically induced ground failure, due to improper grading and soil compaction or discontinuity of naturally occurring soils; however, strong ground shaking often greatly exacerbates soil conditions already potentially prone to differential settlement, resulting in distress to overlying structures. Elongated structures, such as pipelines, are especially prone to damage as a result of differential settlement. Pipe connections at storage facilities are especially vulnerable to the differing earthquake response between buried pipe and rigid structures (California Division of Mines and Geology 1988).

*Earthquake-Induced Landslides*

The State of California has mapped mountainous areas that are potentially prone to seismically induced slope failures, including, rockfalls, debris flows, slumps, and landslides. Based on these maps, the west-facing slopes immediately east of the Project Site are prone to earthquake-induced landslides. In addition, the slopes along the east side of Arroyo Pescadero (Figure 4.4-1), which is traversed by the proposed pipeline route, are prone to landslides. More specifically, these slopes are an area where previous occurrence of landslide movement or local, topographic, geological, geotechnical, and subsurface water conditions indicate a potential for permanent ground displacements (California Department of Conservation, Division of Mines and Geology 1999). In addition, see the discussion of slope stability in Section 4.4.1.5, Geotechnical Hazards.

### 4.4.1.5 Geotechnical Hazards

#### Expansive Soils

Expansive soils swell or heave with increases in moisture content and shrink with decreases in moisture content. Montmorillonitic clays are most susceptible to expansion. Structure foundations constructed on expansive soils require special design considerations (California Building Code 2010). Artificial fill and alluvial soils at the Project Site have a very low to moderate expansion potential (Heathcote Geotechnical 2011).

#### Hydroconsolidation

Hydroconsolidation occurs when soil layers collapse (settle), as a result of saturation under loads. Natural deposits susceptible to hydroconsolidation are typically aeolian, alluvial, or colluvial materials, with high apparent strength when dry. The dry strength of the materials may be attributed to the clay and silt constituents in the soil and the presence of cementing agents (i.e. salts). Capillary tension may also bond soil grains. Once these soils are subjected to excessive moisture and foundation loads, the constituency, including soluble salts or bonding agents, is weakened or dissolved, capillary tensions are reduced, and collapse occurs, resulting in settlement. A geotechnical investigation completed for the Project Site did not specifically include an assessment of hydroconsolidation; however, the report provided structural recommendations for soil settlement, which is related to hydroconsolidation. Artificial fill deposits, which are present at the Project Site to a maximum depth of 10 feet, can be prone to hydroconsolidation if not properly compacted. The younger alluvial materials at the Project Site, which are also generally prone to hydroconsolidation, are primarily located within the active stream channels of La Canada Verde and Arroyo Pescadero creeks.

#### Subsidence

One of the most serious environmental problems caused by oilfield operations within the Los Angeles Basin has been subsidence, which exists in virtually every oil field within the Los Angeles Basin. Subsidence is caused by the reduction of pore pressure within the reservoir resulting from fluids production. The resulting increase in the effective stress causes compaction, which is propagated to the surface, typically causing a bowl-shaped subsidence at the surface, centered over the oil field (Chilingar and Endres 2005).

The most dramatic example of subsidence damage has taken place in the Wilmington Oil Field, near Long Beach. The area that subsided is intensively industrialized and initially was only 5 to 10 feet above sea level. In 1966, 29 feet of subsidence was measured in this area, placing much of the area well below sea level and requiring extensive construction of dikes and raising of dock facilities. Surface deformation within the subsidence bowl caused extensive damage to pipelines, railroad tracks, and buildings (California Department of Conservation, Division of Mines and Geology 1973). In addition, an unusual set of earthquakes were triggered by subsidence-induced fault movement. Damaging shocks occurred in 1947, 1949, 1951, 1954, 1955, and 1961 (Kovach 1974).

Subsidence bowls have been associated with the Inglewood, Long Beach, and Huntington Beach oil fields along the Newport-Inglewood Fault Zone. In addition, minor localized differential subsidence has been documented over the Dominguez oil field. Based on work completed by Hamilton and Meehan (1971) and Barrows (1974), the maximum cumulative subsidence of any of the areas along the Newport-Inglewood Fault Zone was centered over the Inglewood Oil Field, where 67,000 acre-feet of oil, water, and sand had been withdrawn from shallow production horizons by 1971. Since 1971, water injection into the shallow production horizons has limited the overall withdrawals from these horizons. Subsidence is often accompanied by large-scale earthcracking, and in some cases the earthcracking includes horizontal and/or vertical movement, creating incipient or actual faulting. Although the precise failure mechanism is unclear, subsidence may have contributed to failure of the former 20-acre Baldwin Hills Reservoir in 1963, killing five people and damaging or destroying 277 homes. The reservoir was built on a small splay of the Newport-Inglewood Fault, known as the Reservoir Fault.

### Existing Fill

Artificial fill is soil and rock material that has been excavated from one area and placed in another area to raise the ground level. Uncontrolled artificial fills are considered unsuitable for supporting structures and other improvements for many reasons, including: high voids that may collapse or consolidate upon loading; decayed high organics that leave additional voids or high moisture soils that compress; inconsistent fill mixtures that may perform differently; changes in consistency over short spans that lead to differential settlement; uneven expansion potential that may result in differential movement of foundation elements; and lack of proper benching that may lead to fill creep.

Older controlled fills tend to be prone to hydroconsolidation, excessive settlements, or creep. This is due to the change of compaction methods and efforts (i.e., three-layer method versus five-layer method for maximum density determinations), experience in keyways, subdrains, benching, and many other factors. In addition, older fills may lose integrity due to several factors, including bioturbation, organic material decay, shrink swell cycles, and other mechanisms that adversely affect the fills. Therefore, custom and practice in the industry typically dictates that these types of fills not be relied on for structural support of foundations or slabs. Typical mitigations range from total removal to specially designed structural elements or in situ treatments. Existing fill, up to 10 feet thick, was encountered at the site as a result of previous grading related to oil field activities (Heathcote Geotechnical 2011).

### Compressible Soils

Compressible soils consist of low density clays and silts that are prone to high strain rates, resulting in consolidation of the layers with reduced groundwater levels, increased fill, or foundation loading. Consolidation, when soils decrease in volume, occurs when stress applied to a soil causes the soil particles to pack together more tightly, therefore reducing its bulk volume. When this occurs in a soil saturated with water, water and air will be squeezed out of the soil. A geotechnical investigation completed for the Project Site did not specifically include an assessment of compressible soils; however, the report provided structural recommendations for soil settlement, which is related to compressible soils.

### Slope Stability

Slope failures, also commonly referred to as landslides, include many phenomena that involve the downslope displacement and movement of material, either triggered by static (i.e., gravity) or dynamic (i.e., earthquake) forces. Exposed rock slopes undergo rockfalls, rockslides, or rock avalanches, while soil slopes experience shallow soil slides, rapid debris flows, and deep-seated rotational slides. Landslides may occur on slopes of 15 percent or less; however, the probability is greater on steeper slopes that exhibit old landslide features such as scarps, slanted vegetation, and transverse ridges. Landslides typically occur within slide-prone geologic units that contain excessive amounts of water, are located on steep slopes, or where planes of weakness are parallel to the slope angle.

As previously discussed under Secondary Seismic Hazards, the State of California has mapped mountainous areas that are potentially prone to seismically induced slope failures, including, rockfalls, debris flows, slumps, and landslides. Based on these maps, the west-facing slopes immediately east of the Project Site and along portions of the North Access Road are prone to earthquake-induced landslides. In addition, the slopes along the east side of Arroyo Pescadero (Figure 4.4-1), which is traversed by the proposed pipeline route, are prone to landslides. More specifically, these slopes are an area where previous occurrence of landslide movement or local, topographic, geological, geotechnical, and subsurface water conditions indicate a potential for permanent ground displacements (California Department of Conservation, Division of Mines and Geology 1999).

In addition, a geotechnical investigation of the Project Site indicated the topography is prone to surficial slope failure, due to the friable nature of the Fernando Formation, which forms the slopes within the Project Site. Bedding within the Fernando Formation also dips out of slope, creating adverse, or unsupported bedding conditions, which are prone to failure, especially if undercut at the toe during construction. In addition, small, cross-bedding landslides and surficial slope failures were noted along La Canada Verde Creek, located immediately downslope of the Project Site (Heathcote Geotechnical 2011).

## 4.4.2 Regulatory Setting

### 4.4.2.1 California Building Code

The California Building Standards Commission provides a minimum standard for building design with the California Building Code, which is based on the International Code Council but has been modified for California conditions. Chapter 23 of the California Building Code contains specific requirements for seismic safety. Chapter 29 of the California Building Code regulates excavation, foundations, and retaining walls. Chapter 33 of the California Building Code contains specific requirements pertaining to site demolition, excavation, and construction to protect people and property from hazards associated with excavation cave-ins and falling debris or construction materials. Chapter 70 of the California Building Code regulates grading activities, including drainage and erosion control. Construction activities are subject to occupational safety standards for excavation, shoring, and trenching, as specified in California Occupational Health and Safety Administration (Title 8 of the California Code of Regulations) and in Section A33 of the California Building Code.

#### 4.4.2.2 The Alquist-Priolo Earthquake Fault Zone Act of 1994

The criteria most commonly used to estimate fault activity in California are described in the Alquist-Priolo Earthquake Fault Zone Act, which addresses only surface fault-rupture hazards. These legislative guidelines determine fault activity status and are based on the age of the youngest geologic unit offset by the fault. As previously discussed, an active fault is described by the California Geological Survey as a fault that has "had surface displacement within Holocene time." A potentially active fault is defined as "any fault that showed evidence of surface displacement during Quaternary time (within the last 1.6 million years)." This legislation prohibits the construction of buildings used for human occupancy on active and potentially active surface faults. However, only those potentially active faults that have a relatively high potential for ground rupture are identified as Alquist-Priolo Earthquake Fault Zones. Therefore, not all active or potentially active faults are zoned under the Alquist-Priolo Earthquake Fault Zone Act, as designated by the State of California.

#### 4.4.2.3 Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was created to map and address non-surface fault rupture hazards, including liquefaction and earthquake-induced landslides, pursuant to the Seismic Hazards Mapping Act (Public Resources Code, Chapter 7.8, Section 2690 et seq.). The purpose of the Seismic Hazards Mapping Act is to reduce the threat of seismic hazards to public safety and to minimize the loss of life and property, by identifying and mitigating these seismic hazards.

Once Official Seismic Hazard Zones Maps are released, cities and counties affected by the Official Seismic Hazard Zone Maps must require a site-specific geotechnical investigation be conducted within the Zones of Required Investigation, to identify and evaluate seismic hazards and formulate mitigation measures prior to permitting most developments designed for human occupancy.

A copy of each approved geotechnical investigation, including the mitigation measures, is required to be submitted to the California Geological Survey within 30 days of approval of the investigation. Additional guidance regarding the responsibilities of local agencies, guidelines for evaluating and mitigating seismic hazards, as well as the text of the Seismic Hazards Mapping Act, are contained within Special Publication 117A - Guidelines for Evaluating and Mitigating Seismic Hazards in California (California Geological Survey 2008). In addition, local agencies are to incorporate the Seismic Hazard Zone Maps into their Safety Element and the Natural Hazard Disclosure Statement. The Seismic Hazards Mapping Act also requires sellers of real property to disclose to buyers if the property is within a Zone of Required Investigation.

### 4.4.2.4 California Division of Oil, Gas, and Geothermal Resources

The California Division of Oil, Gas, and Geothermal Resources regulates production of oil and gas, as well as geothermal resources, within the State of California. The DOGGR regulations, defined in California Code of Regulations, Title 14, Chapter 4, include well design and construction standards, surface production equipment and pipeline requirements, and well abandonment procedures and guidelines.

- The California Division of Oil, Gas, and Geothermal Resources regulates well abandonment procedures to ensure effectiveness in preventing migration of oil and gas from a producing zone to shallower zones, including potable groundwater zones.
- The California Division of Oil, Gas, and Geothermal Resources overseas well operations. When an operator ceases well operation or production, state law requires the well is abandoned within a reasonable time period.

Regulations require well operators to maintain detailed records of abandonment operations and file copies with the California Division of Oil, Gas, and Geothermal Resources. In addition, California Division of Oil, Gas, and Geothermal Resources regulates environmentally sensitive pipelines, which are defined under California Code of Regulations Section 1760 as:

- A pipeline located within 300 feet of any public recreational area, or a building intended for human occupancy, that is not necessary to the operation of the production operation, such as residences, schools, hospitals, and businesses;
- A pipeline located within 200 feet of any officially recognized wildlife preserve or environmentally sensitive habitat that is designated on a United States Geological Survey topographic map, designated waterways, or other surface waters, such as lakes, reservoirs, rivers, canals, creeks, or other water bodies that contain water throughout the year;
- A pipeline located within the coastal zone, as defined in Section 30103(b) of the Public Resources Code; and
- Any pipeline for which the Supervisor determines there may be a significant potential threat to life, health, property, or natural resources, in the event of a leak, or that has a history of chronic leaks;

California Code of Regulations section 1720 defines a "critical" well as 1) any well within 300 feet of a building intended for human occupancy or an airport runway; and 2) within 100 feet of a dedicated public street, highway or railway, navigable body of water, any periodic high-density population, a public recreational facility, or an officially recognized wildlife preserve. Critical wells that have sufficient pressure to allow fluid-flow to the surface, shall have safety devices as specified by DOGGR (section 1724.3).

California Code of Regulations, Title 14, Section 1774 requires a pipeline management plan for environmentally sensitive pipelines.

### 4.4.3 Significance Criteria

The California Environmental Quality Act (CEQA) Guidelines indicate that a substantial adverse impact would occur if a project would expose people or structures to major geologic hazards. This recognizes any and all unstable geologic conditions as a result of construction, as well as hazards associated with earthquakes, ground shaking, ground movement, fault rupture, groundwater, and other geologic hazards, features, or events. In terms of construction, significant adverse impacts are determined based on whether construction of the project would generate unstable geologic conditions lasting beyond the short-term construction phase.

In accordance with Appendix G of the CEQA Guidelines, the Project would have a potentially significant geology and soils impact if it were to cause one or more of the following conditions:

Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

- Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map or based on other substantial evidence of a known fault;
- Strong seismic ground shaking;
- Seismic-related ground failure, including liquefaction; and
- Landslides;

Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in onsite or offsite landslides, lateral spreading, subsidence, liquefaction, or collapse (hydroconsolidation);

Be located on expansive soil, as defined in the 2007 CBC, creating substantial risks to life or property; and

- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater (Section 4.10, Wastewater, discusses wastewater).

In addition, impacts would be considered significant as a result of deterioration of components of oil field infrastructure due to corrosion, weathering, fatigue, or erosion that could reduce structural stability.

See Section 4.8, Hydrology and Water Resources, for impacts related to soil erosion.

### 4.4.4 Project Impacts and Mitigation Measures

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.1 | Seismically induced ground shaking could damage proposed structures and infrastructure, potentially resulting in loss of property, risk to human health and safety, and oil spills. | Drilling and Testing, Design and Construction, Operations and Maintenance | Less Than Significant With Mitigation |

As illustrated on Figures 4.4-2 and 4.4-3, the active Whittier Fault is at its closest point approximately 1,500 feet north and northeast of the Project Site and proposed pipeline route, respectively. In addition, the Puente Hills blind fault system underlies the Project Area. Because the surface trace of the Whittier Fault does not traverse the Project Area, the potential for fault surface rupture is low. However, up to 60 directionally drilled wells would potentially be completed across the Whittier Fault and/or the Puente Hills Thrust Fault. In the event that an earthquake occurred along either of these faults, the integrity of the well bore would potentially be comprised at the point where the borehole traverses the fault. In the unlikely event that this occurred, under a worst-case scenario, the oil well boreholes would potentially be sheared and sealed, thus preventing additional oil and gas production from that well. Similarly, injection well boreholes would potentially be sheared and sealed, thus preventing additional disposal of produced water in that well. Although such a scenario would necessitate well abandonment and would be detrimental to oil and gas production and associated disposal operations, the potential for spills or releases of oil and gas or produced water to the environment would be lessened with respect to normal drilling, production, and disposal activities, due to partial or complete sealing of the well as a result of the seismically induced ground motion.

Although the potential for liquefaction is low at the Project Site, areas where the proposed pipeline traverses alluvial filled canyon bottoms would be prone to liquefaction. In addition, other earthquake-related hazards, such as ground acceleration and ground shaking cannot be avoided in the Whittier region, and in particular in the vicinity of the Whittier Fault and Puente Hills thrust fault. Strong-to-intense ground shaking due to an earthquake on these or other regional active faults would potentially result in peak ground accelerations of 0.4861 g. Such ground movement could cause differential settlement and lateral spreading, resulting in potential damage of proposed oil and gas drilling equipment, proposed pipelines, and related Project facilities. Such damage would potentially result in a release of oil and gas into the environment.

As discovered during the 1971 San Fernando earthquake and the 1994 Northridge earthquake, existing building codes are often inadequate to completely protect engineered structures from hazards associated with large ground accelerations. Therefore, potential seismic impacts and associated damage to structures from a major earthquake on the nearby Whittier Fault, Puente Hills thrust fault, or any other regional fault, would be considered significant.

*Mitigation Measures*

*GR-1a* *Proposed drilling, production, processing, storage, and transportation infrastructure shall be designed and constructed to withstand anticipated horizontal and vertical ground acceleration in the Project Area, based on the California Building Code. The calculated design base ground motion for project components shall consider the soil type, potential for liquefaction, and the most current and applicable seismic attenuation methods that are available.*

*GR-1b* *All surface facilities and equipment shall have suitable foundations and anchoring design, surface restraints, and moment-limiting supports to withstand seismically induced groundshaking.*

*GR-1c* *All conceptual geotechnical recommendations provided by Heathcote Geotechnical (2011) shall be followed during grading and construction at the Project Site. In addition, a Registered Civil Engineer and Certified Engineering Geologist shall perform an updated geotechnical evaluation of the Project Site, as the proposed building pad and slope configuration has changed since completion of the geotechnical report completed in 2010 (Heathcote Geotechnical 2011). The updated evaluation shall include an estimation of both vertical and horizontal anticipated peak ground accelerations, since the Heathcote Geotechnical report only included horizontal peak ground acceleration values.*

*GR-1d* *This report shall be completed prior to completion of the final project design and shall be submitted to the City of Whittier for review and approval and any new recommendations not included in the Heathcote Geotechnical (2011) report shall be adhered to. The project design must conform to the recommendations within the updated geotechnical evaluation.*

*GR-1e* *All proposed slope construction, roadways, and work pads shall be properly engineered, with fill placed in accordance with requirements of the 2011 County of Los Angeles Building Code (Title 26), which is based on the 2010 California Building Code and the 2009 International Building Code.*

*GR-1f* *All proposed pipelines shall be placed in properly constructed trenches and backfilled with bedding and engineered fill that increases the freedom of movement of the pipelines, or alternatively anchored to prevent pipeline movement, as determined by a California Registered Civil Engineer, in accordance with California Building Code, 2010, Los Angeles County requirements, and the American Public Works Association Greenbook.*

*GR-1g* *All facilities and equipment, including spill containment berms and Project-related pipelines, shall be designed for the seismic loading in accordance with applicable codes, including the California Building Code, 2010.*

*GR-1h* *The Applicant shall cease any non-essential drilling and production activities and inspect all project-related facilities, equipment, and pipelines following any seismic event that generates a ground acceleration of 15 percent of gravity. The*

*Applicant/Operator shall prepare a written report of all inspections and findings to the City for review and approval prior to the recommencement of any operations. The City will respond to the Applicant within 5 working days of the report submittal.*

*Residual Impacts*

Implementing mitigation measures GR-1a through GR-1g would reduce the severity of seismic-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.2 | Moderately expansive soils are prone to swelling and shrinking as a result of increased or decreased water content, which could potentially damage proposed structures and infrastructure, resulting in loss of property and oil spills. | Drilling and Testing, Design and Construction | Less Than Significant with Mitigation |

Onsite soils consist of interbedded sand, silt and clay, which have a very low to medium soil expansion potential. Expansive soils can heave foundations, slabs, and adversely deflect pipelines. These adverse effects could result in damage or catastrophic failure to the Project components. Foundations constructed on expansive soils require special design considerations to mitigate the hazard. Failure to implement these measures could result in a significant impact.

*Mitigation Measures*

Mitigation measure GR-1c shall be completed in association with expansive soil impacts. In addition, mitigation measure GR-2 is recommended.

*GR-2* *Thickened slabs, extending slab edges, and additional reinforcement shall be utilized to reduce negative impacts resulting from expansive soil movement if any construction occurs within moderately expansive soils. In addition, the use of a capillary break under slabs shall be utilized to reduce the potential for moisture transport and pumping that leads to moisture infiltration as a result of heat and moisture gradients. An alternative would be the use of low to non expansive soils for slab support, which would eliminate the potential risk. This can be accommodated by importing select materials. Select grading techniques during grading could utilize the granular soils in site for subsequent use. Measures shall be as described or as otherwise approved by the City Engineer.*

*Residual Impacts*

Implementing mitigation measure GR-2 would reduce the severity of expansive soil-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.3 | Existing uncertified fill onsite could potentially be subject to hydroconsolidation, excessive settlement, expansive soil shrink and swell, and differential settlement/expansion, thus potentially damaging proposed structures and infrastructure, resulting in loss of property and oil spills. | Drilling and Testing, Design and Construction | Less Than Significant With Mitigation |

Based on the report prepared by Heathcote Geotechnical (201), a review of aerial photographs, and observations of the site, uncertified fill has been placed across the site at various locations, to a depth of approximately 10 feet. The exact locations and the horizontal and vertical limits of uncertified fill have not been clearly discerned. Existing uncertified fill onsite could potentially be subject to hydroconsolidation, excessive settlement, expansive soil shrink and swell, and differential settlement/expansion, thus potentially damaging proposed structures and infrastructure, resulting in loss of property.

*Mitigation Measures*

Mitigation measure GR-1c shall be completed in association with artificial fill impacts.

*Residual Impacts*

Implementing mitigation measure GR-1c would reduce the severity of uncertified fill-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.4 | Landslide prone slopes are present in the Project Area. Such slopes could potentially damage proposed structures and infrastructure, resulting in loss of property and oil spills. | Drilling and Testing, Design and Construction | Less Than Significant With Mitigation |

The California Division of Mines and Geology has mapped mountainous areas that are potentially prone to seismically induced slope failures, including, rockfalls, debris flows, slumps, and landslides. Based on these maps, the west-facing slopes immediately east of the Project Site are prone to earthquake-induced landslides. In addition, the slopes along the east side of Arroyo Pescadero (Figure 4.4-1), which is traversed by the proposed pipeline route, are prone to landslides. In addition, a geotechnical investigation of the Project Site (Heathcote Geotechnical 2011) indicated the topography is prone to surficial slope failure, due to the friable nature of the Fernando Formation, which forms the slopes within the Project Site.

Bedding within the Fernando Formation also dips out of slope, creating adverse, or unsupported bedding conditions that are prone to failure, especially if undercut at the toe during grading and construction. The overall gross stability of the slopes directly adjacent to or east of the Project

Site has a factor of safety of 1.93. The standards from the California Building Code (2010) mandate a factor of safety of 1.5 for finished stability and 1.1 for seismic stability. The seismic gross factor of safety for the overall stability of the hillside range is 1.47. Therefore, these slopes will have a factor of safety above 1.1, with respect to seismic stability. However, the slopes are not surficially stable in general and surficial slope failures were observed in abundance (Heathcote Geotechnical 2011). This is considered a potentially significant impact.

*Mitigation Measures*

Mitigation measure GR-1c shall be completed in association with slope stability impacts.

*Residual Impacts*

Implementing mitigation measure GR-1c would reduce the severity of slope stability-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.5 | Temporary excavations could impact and adversely affect adjacent properties or de-stabilize the existing hillside. | Drilling and Testing, Design and Construction | Less Than Significant with Mitigation |

The proposed Project may involve numerous proposed temporary excavations for grading, slope and landslide repair, inadequate soil removal, and trench excavations. Proposed temporary cuts are anticipated to be approximately 5 to 20 feet. Temporary excavations into the existing alluvial deposits at slopes greater than approximately 2:1 (horizontal to vertical) may be prone to collapse, which could remove lateral adjacent support from roads, utilities, and buildings in close proximity to the excavations. Impacts are considered potentially significant.

*Mitigation Measures*

*GR-5a* *Temporary shoring shall be designed to protect the temporary excavations, structures to remain in place, and adjacent properties. This shoring shall be designed by a State of California Registered Civil Engineer to take into account all lateral load parameters. Shoring can include steel cage, timber supports, sheet piling, soil nailing, shotcrete walls, or as otherwise approved by the City Engineer.*

*GR-5b* *Slot cut excavation schemes shall be implemented during grading and foundation excavations to the extent possible, to reduce the potential for failure along temporary cuts, by limiting the area exposed by temporary cuts.*

*GR-5c* *All excavations for structures and buildings shall comply with all applicable regulations of the California Occupational Safety and Hazard Administration guidelines as they pertain to excavations.*

*Residual Impacts*

Implementing mitigation measures GR-5a through GR-5c would reduce the severity of temporary excavation-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.6 | Corrosion could potentially damage the structural components and pipelines which would result in a pipe burst and subsequent oil spill. | Design and Construction, Operations and Maintenance | Less Than Significant With Mitigation |

Soils and bedrock throughout Southern California have varying degrees of sulfate and corrosion potential. Long-term production could result in corrosion of pipelines and other components in contact with the soil and bedrock. Such corrosion could result in oil leaks. No chemical testing was available to assess the various components that may pose a hazard to the proposed concrete and metal components and improvements. If corrosion of pipelines were to occur, the pipelines would be weakened and increase the potential for an oil discharge. Degradation of concrete hold downs, slabs, and foundations could compromise the structural integrity of the elements. Therefore, the impacts due to corrosion would be significant.

*Mitigation Measures*

*GR-6a* *Site specific chemical testing of soil and bedrock shall be performed to assess corrosion and other adverse chemical aspects. A report with the lab tests shall be submitted to the City of Whittier with any appropriate mitigation measures included. The project design must conform to the recommendations within the geotechnical evaluation, or as per the City Engineer, and should occur prior to completion of the final project design.*

*GR-6b* *All buried metal pipelines shall be coated and placed under impressed cathodic protection. To monitor for internal corrosion, corrosion coupons or equivalent measures can be utilized.*

*GR-6c* *External pipe inspections shall be conducted for the exposed pipeline sections to ensure atmospheric coatings are in good conditions. All external inspections shall be documented and reviewed by the operations management and repairs documented, when necessary.*

*GR-6d* *In accordance with California Division of Oil, Gas, and Geothermal Resources pipeline regulations for environmentally sensitive pipelines, a pipeline management plan shall be implemented (Public Resources Code Sections 3013 and 3782). Mechanical testing, including ultrasonic and hydrostatic testing, shall be completed in coordination with the California Department of Conservation Division of Oil, Gas, and Geothermal Resources staff.*

*GR-6e All concrete in contact with the high sulfate or corrosive soils can be Type V concrete in accordance with the 2010 California Building Code.*

*Residual Impacts*

Implementing mitigation measures GR-6a through GR-6d would reduce the severity of corrosion-related impacts to less than significant with mitigation.

| Impact # | Impact Description | Phase | Residual Impact |
|---|---|---|---|
| GR.7 | Oil withdrawal could result in ground subsidence. | Drilling and Testing, Design and Construction, Operations and Maintenance | Less Than Significant With Mitigation |

Subsidence due to oil, gas and groundwater withdrawal generally occurs over a large area. As a result, differential settlement damage due to subsidence is typically only evident in long linear features, such as pipelines, roadways, or aqueducts. No evidence of significant subsidence or problems related to subsidence was identified for the Project Area.

The project will remove an unknown volume of oil, gas, and associated water. In the absence of injection of produced water back into the subsurface, the potential for settlement of the infrastructure increases. Produced water reinjection is a standard practice in the oil and gas industry, not only for the disposal of wastewater, but also to prevent ground subsidence. Although reinjection of produced water in proposed injection wells would substantially reduce the potential for ground subsidence, impacts would be potentially significant in the absence of subsidence monitoring to verify that subsidence is not occurring.

*Mitigation Measures*

*GR-7a Subsidence monitoring shall be completed annually in the vicinity of the wells. Surveying for both vertical and horizontal ground movement shall be completed along the perimeter and throughout the interior of the oil field, utilizing Global Positioning System technology in combination with a network of ground stations. The results shall be forwarded to the Division of Oil, Gas and Geothermal Resources and the City of Whittier for review.*

*GR-7b In the event that the Global Position System monitoring indicates that subsidence is occurring in and/or around the Project Area, wastewater or water reinjection operations shall be increased to alleviate such subsidence. The Applicant shall coordinate with the California Division of Oil, Gas and Geothermal Resources in determining appropriate increased levels of wastewater reinjection operations. The Applicant will also coordinate with the City of Whittier to verify that subsidence has been mitigated sufficiently.*

*Residual Impacts*

Implementing mitigation measures GR-7a and GR-7b would reduce the severity of subsidence-related impacts to less than significant with mitigation.

| **Impact #** | **Impact Description** | **Phase** | **Residual Impact** |
|---|---|---|---|
| GR.8 | Wastewater injection could activate earthquakes along nearby faults. | Drilling and Testing, Design and Construction, Operations and Maintenance | Less Than Significant With Mitigation |

As previously discussed, the Project Site is in proximity to the nearby Whittier Fault and the underlying Puente Fault. Project-related wastewater injection could activate earthquakes along nearby faults. However, adherence to California regulations and oversight by the Division of Oil, Gas, and Geothermal Resources would minimize the potential for an earthquake induced by water injection. Based on California Code of Regulations Title 14, Division 2, Section 1724.10, an accurate, operating pressure gauge or pressure recording device shall be available at all times, and all injection wells shall be equipped for installation and operation of such a device. To determine the maximum allowable surface injection pressure, a step-rate test shall be conducted prior to sustained liquid injection. A step-rate test involves incrementally increasing the injection pressure on a given well until fracture pressures are reached. Maximum allowable surface injection pressure shall be less than the fracture pressure, thereby minimizing the potential for earthquakes and surface ground cracking. The appropriate Division of Oil, Gas, and Geothermal Resources district office shall be notified prior to conducting the test so that it may be witnessed by a Division inspector. Section 4.8.4.2, Potential Water Quality Impacts, includes additional information related to injection wells.

Since injection pressures are maintained below the fracture pressures of the injection zones, the potential for induced earthquakes is low and impacts are considered adverse but not significant.

*Mitigation Measures*

Since seismic impacts related to water injection would be adverse but not significant, no mitigation measures are required.

*Residual Impact*

The residual impact would be less than significant.

### 4.4.5 Other Issue Area Mitigation Measure Impacts

None of the mitigation measures proposed in other issue areas would change the impacts discussed in this section. Therefore, the mitigation measures would not result in additional significant impacts, and additional analysis or mitigation is not required.

### 4.4.6 Cumulative Impacts and Mitigation Measures

In general, the impacts due to the Project can be mitigated to less than significant levels.

Cumulative impacts related to seismically-related ground shaking and associated ground failure, as well as landslides and other impacts, would be similar to what is described for Project-specific impacts. The impacts would be addressed on a project-by-project basis through compliance with existing building codes and any site-specific mitigation measures for individual projects. Remaining impacts associated with the cumulative projects in the vicinity of the project will not have any impacts that result in cumulative impacts, since the impacts are site specific and not significant with mitigation.

Compliance with applicable code requirements and the recommendations of site-specific geotechnical evaluations on a case-by-case basis would reduce cumulative impacts relating to geotechnical hazards to a less than significant level.

All mitigation measures are based on conventional techniques and standards within the industry. All geotechnical hazards can be mitigated to acceptable levels by licensed professionals who will provide guidelines and specifications to mitigate and remediate the specific hazard.

Therefore, cumulative impacts relating to geotechnical hazards would be less than significant.

## 4.4.7 Mitigation Monitoring Plan

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR1-a Proposed drilling, production, processing, storage, and transportation infrastructure shall be designed and constructed to withstand anticipated horizontal and vertical ground acceleration in the Project Area, based on the California Building Code. The calculated design base ground motion for project components shall consider the soil type, potential for liquefaction, and the most current and applicable seismic attenuation methods that are available. | Submit design drawings for all surface facilities and equipment that detail conformance with all applicable building codes and standards. Submit seismic loading calculations for all surface facilities and equipment. | Review and approval of design drawings and seismic loading calculations | Approve design drawings and seismic loading calculations prior to issuance of building permits | City of Whittier |
| GR-1b All surface facilities and equipment shall have suitable foundations and anchoring design, surface restraints, and moment-limiting supports to withstand seismically induced groundshaking. | Fill placed at roadways and work pads | Review and approval of design drawings | Approve design drawings prior to issuance of building permits | City of Whittier |
| GR-1c All conceptual geotechnical recommendations provided by Heathcote Geotechnical (2011) shall be followed during grading and construction at the Project Site. In addition, a Registered Civil Engineer and Certified Engineering Geologist shall perform an updated geotechnical evaluation of the Project Site, as the proposed building pad and slope configuration has changed since completion of the geotechnical report completed in 2010 (Heathcote Geotechnical 2011). The updated evaluation shall include an estimation of both vertical and horizontal anticipated peak ground accelerations, since the Heathcote Geotechnical report only included horizontal peak ground acceleration values. | All buried pipeline shall be placed in engineered trenches and backfilled with bedding and engineered fill, designed by a California Registered Civil Engineer | Observe and test installation of buried pipelines | Monitoring during construction | City of Whittier |

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR-1d This report shall be completed prior to completion of the final project design and shall be submitted to the City of Whittier for review and approval and any new recommendations not included in the Heathcote Geotechnical (2011) report shall be adhered to. The project design must conform to the recommendations within the updated geotechnical evaluation. | Conform with updated geotechnical evaluation | Review and approval | Prior to completion of final project design | City of Whittier |
| GR-1e All proposed slope construction, roadways, and work pads shall be properly engineered, with fill placed in accordance with requirements of the 2011 County of Los Angeles Building Code (Title 26), which is based on the 2010 California Building Code and the 2009 International Building Code. | Establish procedures and manual for all existing facilities and equipment, including spill containment berms and project-related pipelines shall be inspected with respect to seismic integrity. | Observation and inspection. Submit semi-annual reports for review and approval. | Monitor during construction and operations | City of Whittier |
| GR-1f All proposed pipelines shall be placed in properly constructed trenches and backfilled with bedding and engineered fill that increases the freedom of movement of the pipelines, or alternatively anchored to prevent pipeline movement, as determined by a California Registered Civil Engineer, in accordance with California Building Code, 2010, Los Angeles County requirements, and the American Public Works Association Greenbook. | Post earthquake inspection | Cease any drilling and production activities and inspect all project-related facilities, equipment and pipelines following any seismic event that generates a ground acceleration of fifteen (0.15g) percent of gravity. | Inspection for earthquake damage of drilling and production infrastructure immediately following threshold seismic events | City of Whittier |
| GR-1g All facilities and equipment, including spill containment berms and Project-related pipelines, shall be designed for the seismic loading in accordance with applicable codes, including the California Building Code, 2010. | Conform with applicable codes | Observation and inspection. | Monitoring during construction and operations | City of Whittier |

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR-1h The Applicant shall cease any non-essential drilling and production activities and inspect all project-related facilities, equipment, and pipelines following any seismic event that generates a ground acceleration of 15 percent of gravity. The Applicant/Operator shall prepare a written report of all inspections and findings to the City for review and approval prior to the recommencement of any operations. The City will respond to the Applicant within 5 working days of the report submittal. | Post earthquake inspection | Cease any drilling and production activities and inspect all project-related facilities, equipment and pipelines following any seismic event that generates a ground acceleration of fifteen (0.15g) percent of gravity. | Inspection for earthquake damage of drilling and production infrastructure immediately following threshold seismic events | City of Whittier |
| GR-2. Implement GR-1c in association with expansive soil impacts. | See GR-1c. | See GR-1c. | See GR-1c. | See GR-1c. |
| GR-2 Thickened slabs, extending slab edges, and additional reinforcement shall be utilized to reduce negative impacts resulting from expansive soil movement if any construction occurs within moderately expansive soils. In addition, the use of a capillary break under slabs shall be utilized to reduce the potential for moisture transport and pumping that leads to moisture infiltration as a result of heat and moisture gradients. An alternative would be the use of low to non expansive soils for slab support, which would eliminate the potential risk. This can be accommodated by importing select materials. Select grading techniques during grading could utilize the granular soils in site for subsequent use. Measures shall be as described or as otherwise approved by the City Engineer. | Construct buildings with deepened foundations, thickened slabs or import non-expansive soils | Design drawings and site inspections | Prior to permit issuance and during construction | City of Whittier |
| GR-3. Implement GR-1c in association with artificial fill impacts. | See GR-1c. | See GR-1c. | See GR-1c. | See GR-1c. |
| GR-4. Implement GR-1c in association with slope stability impacts. | See GR-1c. | See GR-1c. | See GR-1c. | See GR-1c. |

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR-5a. Temporary shoring shall be designed to protect the temporary excavations, structures to remain in place, and adjacent properties. This shoring shall be designed by a State of California Registered Civil Engineer to take into account all lateral load parameters. Shoring above groundwater levels can range from steel cage to timber supports to sheet piling, soil nailing or shotcrete walls or as otherwise approved by the City Engineer. | Structural plans and calculations | Submit temporary shoring plans and calculations. | Prior to permit issuance | City of Whittier |
| GR-5b. Implement slot cut excavation schemes during grading and foundation excavations to the extent possible to reduce the potential for failure along temporary cuts by limiting the area exposed by temporary cuts. | Structural plans and calculations | Submit temporary shoring plans and calculations. | Prior to permit issuance | City of Whittier |
| GR-5c. All excavations for structures and buildings shall comply with all applicable regulations of the California Occupational Safety and Hazard Administration guidelines as they pertain to excavations. | Structural plans and calculations | Submit temporary shoring plans and calculations. | Prior to permit issuance | City of Whittier |
| GR-6a Site specific chemical testing of soil and bedrock shall be performed to assess corrosion and other adverse chemical aspects. A report with the lab tests shall be submitted to the City of Whittier with any appropriate mitigation measures included. The project design must conform to the recommendations within the geotechnical evaluation, or as per the City Engineer, and should occur prior to completion of the final project design | Corrosion protection measures | Submit chemical testing and corrosion protection mitigation measures for project components. | Prior to permit issuance and annual reports | City of Whittier |
| GR-6b All buried metal pipelines shall be coated and placed under impressed cathodic protection. To monitor for internal corrosion, corrosion coupons or equivalent measures can be utilized. | Corrosion protection measures | Submit chemical testing and corrosion protection mitigation measures for project components. | Prior to permit issuance and annual reports | City of Whittier |

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR-6c External pipe inspections shall be conducted for the exposed pipeline sections to ensure atmospheric coatings are in good conditions. All external inspections shall be documented and reviewed by the operations management and repairs documented, when necessary. | Corrosion protection measures | Submit chemical testing and corrosion protection mitigation measures for project components. | Prior to permit issuance and annual reports | City of Whittier |
| GR-6d In accordance with California Division of Oil, Gas, and Geothermal Resources pipeline regulations for environmentally sensitive pipelines, a pipeline management plan shall be implemented (Public Resources Code Sections 3013 and 3782). Mechanical testing, including ultrasonic and hydrostatic testing, shall be completed in coordination with the California Department of Conservation Division of Oil, Gas, and Geothermal Resources staff. | Corrosion protection measures | Submit chemical testing and corrosion protection mitigation measures for project components. | Prior to permit issuance and annual reports | City of Whittier |
| GR-6e All concrete in contact with the high sulfate or corrosive soils can be Type V concrete in accordance with the 2010California Building Code. | Corrosion protection measures | Submit chemical testing and corrosion protection mitigation measures for project components. | Prior to permit issuance and annual reports | City of Whittier |
| GR-7a Subsidence monitoring shall be completed annually in the vicinity of the wells. Surveying for both vertical and horizontal ground movement shall be completed along the perimeter and throughout the interior of the oil field, utilizing Global Positioning System technology in combination with a network of ground stations. The results shall be forwarded to the Division of Oil, Gas and Geothermal Resources and the City of Whittier for review. | Subsidence monitoring in the vicinity of the field. GPS survey for both vertical and horizontal ground movement along the perimeter and throughout the interior of the oil field. | Monitor subsidence with GPS technology. | Annually | City of Whittier |

| Mitigation Measure | Requirements | Compliance Verification | | |
|---|---|---|---|---|
| | | Method | Timing | Responsible Party |
| GR-7b In the event that the Global Position System monitoring indicates that subsidence is occurring in and/or around the Project Area, wastewater or water reinjection operations shall be increased to alleviate such subsidence. The Applicant shall coordinate with the California Division of Oil, Gas and Geothermal Resources in determining appropriate increased levels of wastewater reinjection operations. The Applicant will also coordinate with the City of Whittier to verify that subsidence has been mitigated sufficiently. | Increase wastewater reinjection operations in the event that GPS monitoring indicates that subsidence is occurring. | Increase wastewater reinjection operations. | Following monitoring results indicating subsidence | California Division of Oil, Gas and Geothermal Resources and City of Whittier |